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NOUVELLE SÉRIE

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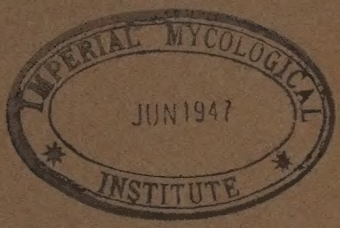

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MECHANICS

A CONTRIBUTION TO THE THEORY OF LONG WAVES

By M. A. LAVRENTIEFF, Member of the Academy of Sciences of the Ukrainian SSR

1. Formulation of Problem. A heavy fluid is supposed to be moving inside a rectangular channel of infinite length. The position of the fluid and its velocity are completely determined by the position of its free surface and the velocity distribution at the initial moment. In the general case the shape of the free surface and the velocity of the fluid at any point vary with the coordinates of the point and with time. A special interest attaches to the case when the field of velocities is independent of time (steady motion) — in the case under consideration the motion of the fluid (assumed to be an ideal fluid) in a channel of infinite length presents a well-known problem on wave motions of a heavy fluid. Here is the formulation of this problem in mathematical terms for the case of a channel of variable length. Let xoy be the coordinate plane parallel to the velocities of the fluid; $\Gamma_0 : y = y_0(x)$, the section of the bottom; and $\Gamma : y = y(x)$, the section of the free surface. The region $D(\Gamma_0, \Gamma)$ is bounded by the lines Γ_0 and Γ. Let $\xi o \eta$ be an auxiliary plane of the complex variable $\zeta = \xi + i\eta$ in which plane a strip $0 < \eta < h$ of width h is supposed to be given. Under this notation we are to determine the line Γ such that:

1) $\lim \frac{1}{2l} \int_{-l}^{+l} \{y(x) - y_0(x)\}\, dx = H$, where H is a given constant, the depth of the channel is $y'(0) = 0$.

2) On conformal mapping $\zeta = f(z)$, $z = x + iy$, $f(\pm\infty) = \pm\infty$ of the region $D(\Gamma_0, \Gamma)$ into the strip $0 < \eta < h$ along the line Γ we have:

$$\frac{\rho}{2} |f'(z)|^2 + \rho g y = C, \qquad (1)$$

where ρ is the density of the fluid, g is the acceleration of gravity, C is the constant of Bernoulli's equation.

In the classical problem of waves we have to put $y_0(x) \equiv 0$; in that case the coordinate system xoy is in motion, being translated with the velocity of the wave.

A set of dimensionless parameters is now to be introduced in the problem. Denoting by a the amplitude of the sought-for wave, by l its length, we put:

$$\lambda = 1 - \frac{1}{H}\sqrt[3]{\frac{h^2}{g}}; \quad \alpha = \frac{a}{H}; \quad \beta = \frac{\max y_0(x) - \min y_0(x)}{H}; \quad \gamma = \frac{l}{H}.$$

On simple considerations of dimensionality it will suffice, when $\beta = 0$; to study the motion in relation to the parameter λ. For $\beta > 0$ the motion will depend upon $y_0(x)$. We shall confine ourselves to the case when y_0 is a periodical function with a period denoted by l_0.

I should like now to point out what I know of the fundamental results relative to this problem. If α is small and the ratio $\frac{\alpha}{\lambda}$ is also small, the boundary conditions (1) can be linearized, and for $\beta=0$ the respective linear problem admits of en exhausting elementary solution. On the same line a set of problems have been solved for a concretely given function $y_0(x)$, and N. E. Kochin has investigated the case when Γ_0 is a step and β is small. On the same assumptions that α and $\frac{\alpha}{\lambda}$ are small and $\beta=0$; the apparatus of integral equations was used to establish the theorem of the existence of wave motions under strict boundary conditions (1) and to obtain some general properties of the wave (case approaching linearity). For an essentially non-linear case ($\frac{\alpha}{\lambda}$ is finite) numerous approximate methods for constructing the solution when $\beta=0$ have been developed. Thus, Rayleigh for small λ gave an approximate theory of waves of any length and obtained an approximate form of isolated wave.

In the present communication I set forth: 1) a new method for constructing an approximate solution of the general problem with the estimation of the error; the process converges; if there exists a solution; 2) the possibility of supporting the theory of Rayleigh by a rigorous argumentation and the estimation of the error involved in his method; 3) some general properties of the solutions in case $y_0(x)$ is a periodical function.

2. Construction of Problem. We take $\Gamma_i: y=y_i(x)$ to denote the stream-line of the flow sought for. In the plane of the complex potential ζ the stream-line passes into a straight line $\eta=\frac{h_i}{n}$, where n is any fixed integer. The line Γ_0 will coincide with the section of the bottom, and the line $\Gamma_n=\Gamma'$ will give the free surface of the fluid. On the basis of a formula for approximate conformal mapping presented in an earlier paper of mine [1], a system of ordinary differential equations can easily be constructed whose solution will approximately give the stream-line Γ_i. For n-th approximation this system has the form:

$$y''_i\{(y_{i+1}-y_i)^2+(y_i-y_{i-1})^2\}(1+y_i'^2)^{-\frac{3}{2}}-$$
$$-2y'_i(1+y_i'^2)^{-1}\{(y_{i+1}-y_i)(y'_{i+1}-y'_i)+(y_i-y_{i-1})(y'_i-y'_{i-1})\}+$$
$$+y_{i+1}+y_{i-1}-2y_i=0, \quad i=1, 2, \ldots, n-1;$$

$$\frac{(1+y_n'^2)h^2}{(y_n-y_{n-1})^2}\left\{\frac{y_n-y_{n-1}}{(1+y_n'^2)^{3/2}}y''_n-\frac{2y'_n}{1+y_n'^2}(y'_n-y'_{n-1})+1\right\}+2gy_n=C.$$

The constants of integration and the parameter C are to be determined from the following conditions: 1) $\lim\limits_{l\to\infty}\int\limits_{-l}^{+l} y_n(x)\,dx=H$, $y'_n(0)=0$; 2) function $y_n(x)$ should be bounded and all the rest satisfy the inequalities:

$$y_0(x)<y_1(x)<\ldots<y_n(x)=y(x).$$

With $n=1$ and with $y_0(x)\equiv 0$ our system reduces to a single equation equivalent to that which Rayleigh obtained on essentially different reasoning.

If the general problem proposed above admits of a single solution, the system admits of a single solution as well, and for $n\to\infty$ the lines Γ_i tend uniformly to the respective stream-lines, the error being of order $\frac{1}{n^2}$. If the problem admits of a single solution for a certain fixed value of the parameter C, then the system (with n sufficiently great) also admits of a single solution for the same fixed value of C, the rate of convergence is unaltered.

3. Rayleigh's Waves. Several propositions may now be followed from Rayleigh's theory [the first approximation of the system for $y_0(x) \equiv 0$]. Their rigorous proof is obtained from accuracy estimates of the first approximation and by using a set of variational theorems of the theory of conformal mappings, such as were established by me in an earlier paper [2] and their like.

Theorem 1. *With* $\lambda < 0$ *the problem allows the single solution* $y = H$; *with* $\lambda > 0$ *and sufficiently small there exists an interval of values of* C

$$C_0 = \frac{\rho}{2}\left(\frac{h}{H}\right)^2 + \rho g H \leqslant C \leqslant C_1,$$

to each of which corresponds a single solution of the problem. For $C = C_0$ *we have the trivial solution* $y = H$. *For* $C_0 < C < C_1$ *we have a wave — the cross-section of the free surface is a periodic function with a period* 2ω *depending upon* C, $y(x + 2\omega) = y(x)$; $y(-x) = y(x)$. *In every interval of the period,* $y(x)$ *admits of one maximum and one minimum; the amplitude of the wave and the period* ω *are monotonously increasing functions of* C *and of the crest's height* $y(0)$. *For* $C = C_1$ *the function* $y(x)$ *admits of one maximum at* $x = 0$ *and then we have an isolated wave.*

4. Curvilinear Periodical Bottom. On the basis of the method outlined in § 2 and 3 various propositions can as well be obtained relative to the motion of an ideal fluid in a channel of variable depth. We shall restrict ourselves to the case when $y_0(x)$ is symmetrical with respect to the y-axis, has the period 2ω, and when $\beta / |\lambda|$ is a small number, and λ does not exceed a certain positive sufficiently small constant.

Theorem 2. *For* $\lambda < -\lambda_0(\beta)$, $\lambda_0 > 0$, $\lim\limits_{\beta \to 0} \lambda_0 = 0$, *the problem has a solution which is the unique solution and is given by the periodic function* $y(x)$ *with period* 2ω. *The amplitude of the wave grows with* λ, *that is, with increasing depth.*

Theorem 3. *Let* $\lambda_2 > \lambda > \lambda_1(\beta)$, *where* $\lambda_1 > 0$, $\lim\limits_{\beta \to 0} \lambda_1 = 0$ *and* λ_2 *is small enough. Then for an* ω_0 *smaller than a certain constant* $\overline{\omega}_0$ *depending on* β *and* λ, *there always exists a unique periodic motion with period* $2\omega_0$. *Along with it there exists a one-parameter family of quasi-periodic solutions, one of which (the limiting one) has the asymptotic period* $2\omega_0$.

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25. VIII. 1943.

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ELECTRICAL ENGINEERING

SYNCHRONOUS INDUCTION MACHINE TURNING AUTOMATICALLY TO ASYNCHRONOUS WORK WHEN OVERLOADED

By K. I. SHENFER, Member of the Academy

Considerable overloads are known to cause synchronous machines; after passing the limit of stability, to fall out of synchronism, with the result that the normal work is no longer possible.

This drawback could be removed if we were successful in designing such a system of excitation that the losing of synchronism by an synchronous machine would not affect its load significantly, and its satisfactory operation

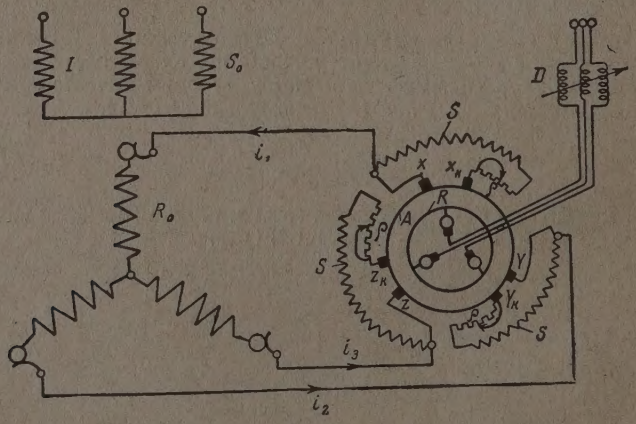

Fig. 1

would be secured under asynchronous as well as synchronous load without any switching-over manipulations.

These conditions can be fulfilled under the scheme represented in Fig. 1, where S_0—R_0 are stator and rotor of main asynchronous machine; S—S—S, stator of three-phase collector machine with windings as in the Schrage type motor; R, three-phase winding of rotor, connected to the network by means of three contact rings; A, winding with collector on the same rotor with winding; x—x_k, y—y_K, z—z_K, brushes on the collector movable to opposite sides, as in the Schrage motor; ρ—ρ—ρ, active resistances; D, reactor with regulation.

The Schrage type machine (Fig. 1) is not connected mechanically with the rotor of the main motor. The control of the excitation current $i_1 = i_2 + i_3$ is either by shifting the brushes on the collector A or by varying the voltage on the contact rings of the armature R with the aid of the reactor D.

At a certain position of the brushes $x - x_k, y - y_k, z - z_k$ the three-phase exciting machine falls into synchronism, and the value of the currents $i_1 = i_2 + i_3$ stops oscillating periodically with the slip frequency; so that i_1; i_2 and i_3 are now direct currents. Under these conditions the main machine S_0—R_0 turns also to synchronism, and its rotor R_0 begins rotating with synchronous velocity.

The regulating of the current strengths i_1; i_2, i_3 may be effected under the scheme of Fig. 1 either by shifting the brushes on the collector A or by changing the voltage on the contact rings of the rotor R. In that way Mordey's curves can be obtained for the machine S_0—R_0 which represent the relation between the excitation currents i_1, i_2; i_3 in the rotor R_0 and the alternating current I in the winding of the stator S_0. Experiments have shown that the machine S_0—R_0 does not stop working if, owing to considerable overload or impulse of load, the rotor R_0 falls out of synchronism. When this occurs; an a. c. voltage with the slip frequency of the rotor R_0 appears on the collector of the three-phase exciter instead of the d. c. voltage (Fig. 2).

When the load of the main motor S_0—R_0 has decreased, the motor turns again to synchronous work and its speed is increased up to the synchronous velocity.

Various shemes of connecting an asynchronous motor in concatenation to a Schrage motor have been studied a rather long time ago by I.S. Bruck. The stability of such a system was investigated by him under different conditions of loading and velocity regulation, whereas the present work has been concerned mainly with the three-phase collector machine of the Schrage type used as an universal exciter of direct current and able also to work under overload for alternating current.

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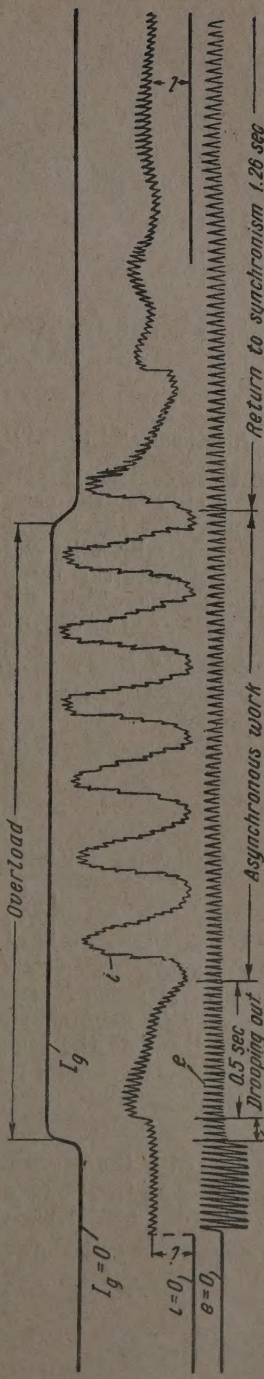

Fig. 2. Process of falling out of synchronism and of returning to synchronism of the machine; I_g, current of load generator; i, current of one of the phases of the main machine (excitation current); e, oscillogram for a 50-period voltage (for time scale)

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PHYSICS

RECIPROCATION THEOREM OF ELECTRODYNAMICS FOR TRANSITORY PROCESSES

By J. N. FELD

(Communicated by N. D. Papalexi, Member of the Academy, 24.VI.1943)

The reciprocation theorem of electrodynamics seems to have been thus far considered only for the case of harmonic oscillations ([1],[2]). In the present work the reciprocation theorem is extended to include the transitory electromagnetic processes, arbitrarily varying with time.

We shall prove this theorem, similarly to the case of harmonic oscillations, using the lemma which is a generalization of a well known Lorentz' lemma ([1]).

1. Generalized Lorentz' lemma. Let us consider two arbitrary electromagnetic fields $\vec{E}_1, \vec{H}_1$ and $\vec{E}_2, \vec{H}_2$, satisfying within some region of space Maxwell equations

$$\left.\begin{aligned} \operatorname{rot}\begin{Bmatrix}\vec{H}_1\\ \vec{H}_2\end{Bmatrix} &= \left\{\frac{4\pi\sigma}{c}+\frac{\varepsilon}{c}\frac{\partial}{\partial t}\right\}\begin{Bmatrix}\vec{E}_1\\ \vec{E}_2\end{Bmatrix}\\ \operatorname{rot}\begin{Bmatrix}\vec{E}_1\\ \vec{E}_2\end{Bmatrix} &= -\frac{\mu}{c}\frac{\partial}{\partial t}\begin{Bmatrix}\vec{H}_1\\ \vec{H}_2\end{Bmatrix}\end{aligned}\right\} \tag{1}$$

with the following initial conditions:

$$\begin{Bmatrix}\vec{E}_1\\ \vec{E}_2\end{Bmatrix} = \begin{Bmatrix}\vec{H}_1\\ \vec{H}_2\end{Bmatrix} = 0 \qquad \text{for } t \leqslant 0. \tag{1a}$$

Electromagnetic parameters of the medium ε, μ, σ involved in the equations (1) are in general some functions of space coordinates. The lemma we want to deduce may be most simply obtained by means of operational method. We introduce therefore the images of the field vectors:

$$\left.\begin{aligned} \vec{\mathfrak{E}}_1 &\doteq \vec{E}_1; \qquad \vec{\mathfrak{H}}_1 \doteq \vec{H}_1\\ \vec{\mathfrak{E}}_2 &\doteq \vec{E}_2; \qquad \vec{\mathfrak{H}}_2 \doteq \vec{H}_2\end{aligned}\right\} \tag{2}$$

connected with the corresponding field vectors by means of well known integral formulae of Carson and Bromwhich ([3]).

We get the equations for the images by substituting into the equations (1) by the operator p the parameter $\frac{\partial}{\partial t}$:

$$\left.\begin{aligned} \operatorname{rot}\begin{Bmatrix}\vec{\mathfrak{H}}_1\\ \vec{\mathfrak{H}}_2\end{Bmatrix} &= \frac{4\pi\sigma+\varepsilon p}{c}\begin{Bmatrix}\vec{\mathfrak{E}}_1\\ \vec{\mathfrak{E}}_2\end{Bmatrix}\\ \operatorname{rot}\begin{Bmatrix}\vec{\mathfrak{E}}_1\\ \vec{\mathfrak{E}}_2\end{Bmatrix} &= -\frac{\mu}{c}p\begin{Bmatrix}\vec{\mathfrak{H}}_1\\ \vec{\mathfrak{H}}_2\end{Bmatrix}\end{aligned}\right\} \tag{3}$$

Since the equations (3) for images do not differ from Maxwell equations for harmonic oscillations in anything but in substitution of $j\omega$ by parameter p, then for images, as for field vectors in the case of harmonic vibrations, the Lorentz' lemma (1) holds:

$$\operatorname{div}[\vec{\mathfrak{E}}_1 \vec{\mathfrak{H}}_2] = \operatorname{div}[\vec{\mathfrak{E}}_2 \vec{\mathfrak{H}}_1]. \tag{4}$$

There exists, evidently, some equation connecting the images of field vectors which corresponds to the equation (4). In order to find it we divide equation (4) by p and subsequently, using some theorems of operational calculus and, particularly, the Borel's lemma, get:

$$\int_0^t \operatorname{div}[\vec{E}_1(t-\tau)\vec{H}_2(\tau)]\,d\tau = \int_0^t \operatorname{div}[\vec{E}_2(\tau)\vec{H}_1(t-\tau)]\,d\tau. \tag{5}$$

Integrating equation (5) over arbitrary space region v, bounded by surface s, within which the equations (1) hold, and applying the Gauss theorem, we transform (5) to the form more suitable for applications:

$$\int_0^t d\tau \int_s [\vec{E}_1(t-\tau)\vec{H}_2(\tau)]\,\vec{ds} = \int_0^t d\tau \int_s [\vec{E}_2(\tau)\vec{H}_1(t-\tau)]\,\vec{ds}. \tag{5a}$$

The field vectors entering equations (5) and (5a) depend on the space coordinates as well, but for the sake of brevity this is not indicated explicitly. The above equations (5), (5a) generalize Lorentz' lemma to include the case of arbitrary transitory processes, satisfying the initial conditions (1a). The generalized Lorentz' lemma may be immediately used in order to prove the reciprocation theorem, which will be given subsequently.

2. Reciprocation Theorem. Let us consider the reciprocation theorem for two arbitrary aerials, which are in some manner placed in the space with parameters ε, μ, σ varying from point to point. We assume the aerials to be perfectly conducting, i. e. the currents in them flowing only over their surfaces.

This represents the actual situation for metallic conductors at radio frequencies quite well. The investigation of finite conductivity would call for the introduction of spatial distribution of emf as well as some complication of the lemma (5a), without any modification of final results. Let us designate by $\vec{E}_1$, $\vec{H}_1$ the field, generated by the first aerial when the external emf $\vec{E}_1^{ext}$ is applied to its surface (in this case the second aerial acts as receiving aerial).

The field generated by the second aerial when the emf $\vec{E}_2^{ext}$ is applied to its surface, will be designated by $\vec{E}_2$, $\vec{H}_2$ (the first aerial is receiving).

Let us apply to the fields $\vec{E}_1$, $\vec{H}_1$ and $\vec{E}_2$, $\vec{H}_2$ the generalized Lorentz' lemma (5a). The surface s will be supposed to consist of the aerial surfaces s_1 and s_2, bounding the space (filled by electromagnetic fields) from the inner side, and the spherical surface of infinite radius, bounding the space from the outer side.

Since the integral over the latter surface vanishes, then the equation (5a) in our case becomes:

$$\int_0^t d\tau \int_{s_1+s_2} [\vec{E}_1(t-\tau)\vec{H}_2(\tau)]\,\vec{ds} = \int_0^t d\tau \int_{s_1+s_2} [\vec{E}_2(\tau)\vec{H}_1(t-\tau)]\,\vec{ds} \tag{6}$$

In order to transform this equation we make use of the electrodynamical conditions for tangential components of the field vectors on the surface of

perfect conductors (aerials) when the external emf are applied:

$$E_{1,t}=\begin{cases}-E_{1,t}^{ext} & \text{on } s_1;\\ 0 & \text{on } s_2\end{cases}\quad E_{2,t}=\begin{cases}-E_{2,t}^{ext} & \text{on } s_2\\ 0 & \text{on } s_1\end{cases} \tag{7}$$

$$[\vec{n}\vec{H}_1]=\frac{4\pi}{c}\vec{i}_2 \text{ on } s_2;\quad [\vec{n}\vec{H}_2]=\frac{4\pi}{c}\vec{i}_1 \text{ on } s_1. \tag{7a}$$

Here $\vec{i}_1$ and $\vec{i}_2$ are the surface densities of currents on the first ant the second aerials when they act as receiving aerials, while $\vec{n}$ is unit vector normal to the corresponding surface.

The direct product of equations (7a) with $\vec{n}$ leads to somewhat other formulation:

$$\vec{H}_1=(\vec{n}\vec{H}_1)\vec{n}-\frac{4\pi}{c}[\vec{n}\vec{i}_2] \text{ on } s_2;$$

$$\vec{H}_2=(\vec{n}\vec{H}_2)\vec{n}-\frac{4\pi}{c}[\vec{n}\vec{i}_1] \text{ on } s_1.$$

Introducing these values of $\vec{H}$ into (6) and taking into account the conditions (7) gives after some simple transformations the desired reciprocation theorem:

$$\int_0^t d\tau\int_{s_1}\vec{E}_1^{ext}(t-\tau)\,\vec{i}_1(\tau)\,ds=\int_0^t d\tau\int_{s_2}\vec{E}_2^{ext}(t-\tau)\,\vec{i}_2(\tau)\,ds. \tag{8}$$

In particular case (which is often realized in praxis) when the external emf is applied to the little section of aerial, within which the current may be considered constant; the reciprocation theorem acquires an especially perspicuous form:

$$\int_0^t I_1(\tau)\,\mathfrak{E}_1(t-\tau)\,d\tau=\int_0^t I_2(\tau)\,\mathfrak{E}_2(t-\tau)\,d\tau. \tag{9}$$

Here I_1 and I_2 are total currents in first and second aerials (when they work as receiving aerials), flowing in the linear section to which the external emf's are applied when the aerials work as transmitting aerials, while $\mathfrak{E}_1=\int\vec{E}_1^{ext}\,\vec{dl}$ and $\mathfrak{E}_2=\int\vec{E}_2^{ext}\,\vec{dl}$ are the total emf's applied to the aerials (dl is the element of length).

Let us, moreover, consider the reciprocation theorem for a case of point sources — that of electrical dipoles. We apply the Lorentz' lemma to the fields $\vec{E}_1, \vec{H}_1$ and $\vec{E}_2, \vec{H}_2$, generated by electrical dipoles situated at the points A_1 and A_2, respectively. Assuming the surface s to consist of two infinitely small spheres s_1 and s_2, enveloping the places occupied by dipoles A_1 and A_2 where the regularity of field vectors is broken, we rewrite the equation (5a) as follows:

$$\int_0^t d\tau\int_{s_1+s_2}[\vec{E}_1(t-\tau)\,\vec{H}_2(\tau)]\,\vec{ds}=\int_0^t d\tau\int_{s_1+s_2}[\vec{E}_2(\tau)\,\vec{H}_1(t-\tau)]\,\vec{ds}. \tag{10}$$

If in the immediate vicinity of both the dipoles there are homogeneous media with parameters ε_1, μ_1, $\sigma_1=0$ and ε_2, μ_2, $\sigma_2=0$*, then the main part of the field

* Throughout all the space, except the immediate vicinity of dipoles, σ may be an arbitrary function of coordinates.

in the neighbourhood of the dipole which generates it is of the form:

$$\left.\begin{aligned} &\text{main part of } \vec{E} = \frac{1}{\varepsilon}\,\text{grad div}\,\vec{\Pi} - \frac{\mu}{c^2}\frac{\partial^2\vec{\Pi}}{\partial t^2} \\ &\text{main part of } \vec{H} = \frac{1}{c}\frac{\partial}{dt}\,\text{rot}\,\vec{\Pi} \\ &\vec{\Pi} = \frac{\vec{p}\left(t - \frac{r}{v}\right)}{r} \end{aligned}\right\} \qquad (11)$$

where $p(t)$ is electrical moment of the dipole.

Going over in the equation (10) to the limit with the radii of spheres s_1 and s_2 tending to zero, and keeping in mind the equations (11) and the initial conditions (1a), we get after simple calculations *

$$\int_0^t \vec{p_1}'(\tau)\,\vec{E}_2(t-\tau)\,d\tau = \int_0^t \vec{p_2}'(\tau)\,\vec{E}_1(t-\tau)\,d\tau. \qquad (12)$$

Here $\vec{E}_1$ ($\vec{E}_2$) is electric vector, generated by the first (second) dipole in the point in which the second (first) dipole is situated.

The equation (12), precisely, characterizes the desired reciprocation theorem for the case of electric dipoles.

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* These calculations but little differ from the similar calculations performed by Sveshnikova ([2]) for the case of harmonic vibrations.

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TECHNICAL PHYSICS

SOME NEW METHODS FOR SPECTRUM ANALYSIS OF MINERAL RAW MATERIALS

By S. A. BOROVICK

(Communicated by S. I. Wawilow, Member of the Academy, 1.VII.1943)

One engaged in the quantitative spectral analysis of sulphide ores is greatly handicapped by the fact that during the burning of the arc the sample to be analysed is apt to be thrown out from the cavity of the carbon electrode. It has been found possible; however; to circumvent this difficulty by covering the cavity, with the sample placed in it; by a lid cut out of a spectrally pure carbon. The lid has an opening 0.5—1 mm wide. As the arc burns, the sample gradually evaporates through the opening and there is no ejection of it from the cavity. Another advantage of this method is the possibility of increasing the sensitivity of spectral determinations in the case of easily evaporated elements (Pb, Bi; Zn, Cd; Ga, Ge; In).

Likewise when we have to deal with the samples in which the element concerned is a part of an organic complex (soil; plant; ash; etc.), the analysis is facilitated by this method and made moreover more sensitive. In the course of these experiments it has been revealed further that the accuracy of spectral determinations is considerably increased by using an a. c. arc; 220 volt; 10—12 ampere. In that way the error was reduced down to 3 per cent; which is a considerable achievement for the arc method. As spectrally pure carbons are difficult to ignite by alternating current; an activator was switched on for a short time; and once the arc had been started burning; it stably continued so without the activator. By means of this method satisfactory results were obtained in analysing for tin such samples as contained 15 to 20 per cent of it; although it has been believed until now that spectral analysis is not fit to give good results in the case of high concentrations.

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BIOPHYSICS

THE ABSOLUTE SCOTOPIC SENSITIVITY OF THE EYE IN THE ULTRAVIOLET AND IN THE VISIBLE SPECTRUM

By N. I. PINEGIN

(Communicated by S. I. Wawilow, Member of the Academy, 30.VIII.1943)

In a previous work (1) we have summed up the results of our measurements of the threshold scotopic and photopic sensitivity in the form of the illumination of the pupil, as made on 9 observers endowed with normal vision, within the range beetween 709 and 302 mμ mercury lines. In 1942 there appeared a paper by Goodeve, Lythgoe and Schneider (2); containing the results of measurements of the scotopic sensitivity, made on 6 observes, including one with a removed lens (aphakic eye), for the lines 365 and 546 mμ.

It is of interest to compare the results of the measurements of scotopic sensitivity obtained by us with those of the above-named authors. Our measurements were made without centering the field of vision for the most sensitive parafoveal region of the retina, after an hour long adaptation to the dark. The writers cited made their measurements with the field of vision centered on the red light spot produced by the source ($\lambda > 800$ mμ), using the parafoveal region of the retina 10° from the centre along the 180° meridian, after a dark adaptation of 10 min.

Let us describe for the sake of comparison only those results that have been obtained by us when eliminating the chromatic aberration by means of negative quartz spectacle lenses of suitable dioptrics.

The authors cited above eliminated the chromatic aberration by focusing the light emergent from the slit of the monochromator with the aid of a lens upon the eye of the observer. The absolute scotopic sensitivity as determined by them is the reciprocal of the retinal illumination; $S_\lambda = \frac{1}{J_\lambda}$.

The retinal illumination was found by us according to the formula

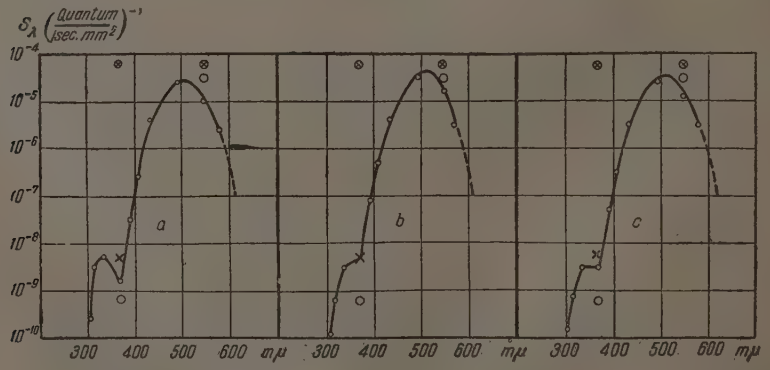
$$J_\lambda = \frac{E_\lambda \cdot 10^{-2}}{h\nu} \cdot \frac{r \cdot \sigma}{a} = \frac{E_\lambda}{h\nu} \cdot 54;$$

where E_λ erg/sec. cm² is the illumination of the pupil; $h\nu$ erg/sec.; the energy quantum of the monochromatic radiation; $r = 0.95$, reflection coefficient at the cornea; $\sigma = 0.5$ cm², area of the pupil (8 mm across); $a = B\left(\frac{f}{d}\right)^2 = 8.8 \times 10^{-3}$ mm², area of the image on the retina; $B = 490$ mm², area of the circular object of observation (25 mm across); $f = 16.95$ mm, anterior focal length of the eye's optical system; $d = 4000$ mm, distance of the object from the first principal plane of the eye; r and σ have been taken equal to those of the authors cited.

Table and figure (*a*—*c*) illustrate the results of measurements of the absolute scotopic sensitivity obtained by these writers and by the author of the present note.

Illumination of the Pupil, Retinal Illumination, and Absolute Scotopic Sensitivity of the Normal Eye in the Ultra-Violet and Visible Spectrum (Pinegin's data)

λ, mμ	E_λ $\frac{\text{erg}}{\text{sec. cm}^2}$	J_λ $\frac{\text{quant}}{\text{sec. mm}^2}$	$S_\lambda \left(\frac{\text{quant}}{\text{sec. mm}^2}\right)^{-1}$	lg S_λ
		1st group (4 observers)		
302	4.79×10^{-4}	3.99×10^{9}	2.51×10^{-10}	−9.6
313	3.58×10^{-5}	3.08×10^{9}	3.25×10^{-9}	−8.5
334	2.11×10^{-5}	1.94×10^{8}	5.16×10^{-9}	−8.3
365	5.65×10^{-8}	5.69×10^{8}	1.76×10^{-9}	−8.8
390	3.25×10^{-6}	3.43×10^{7}	2.92×10^{-8}	−7.5
404—407	3.97×10^{-7}	4.44×10^{6}	2.25×10^{-7}	−6.6
435	2.31×10^{-8}	2.77×10^{5}	3.61×10^{-6}	−5.4
491	3.08×10^{-9}	4.17×10^{4}	2.40×10^{-5}	−4.6
546	6.22×10^{-9}	9.35×10^{4}	1.07×10^{-5}	−5.0
576—579	2.24×10^{-8}	3.57×10^{5}	2.81×10^{-6}	−5.6
		2nd group (4 observers)		
302	1.03×10^{-3}	8.57×10^{9}	1.17×10^{-10}	−9.9
313	1.73×10^{-4}	1.49×10^{9}	6.79×10^{-10}	−9.2
334	3.17×10^{-5}	2.92×10^{8}	3.43×10^{-9}	−8.5
365	1.96×10^{-5}	1.98×10^{8}	5.06×10^{-9}	−8.3
390	1.31×10^{-6}	1.38×10^{7}	7.25×10^{-8}	−7.1
404—407	1.73×10^{-7}	1.93×10^{6}	5.19×10^{-7}	−6.3
435	2.19×10^{-8}	2.63×10^{5}	3.80×10^{-6}	−5.4
491	2.45×10^{-9}	3.32×10^{4}	3.02×10^{-5}	−4.5
546	4.49×10^{-9}	6.75×10^{4}	1.48×10^{-5}	−4.8
576—579	2.02×10^{-8}	3.22×10^{5}	3.11×10^{-6}	−5.5
		Mean values for 9 observers		
302	7.55×10^{-4}	6.28×10^{9}	1.59×10^{-10}	−9.8
313	1.46×10^{-4}	1.26×10^{9}	7.94×10^{-10}	−9.1
334	3.75×10^{-5}	3.45×10^{8}	2.90×10^{-9}	−8.5
365	3.45×10^{-5}	3.48×10^{8}	2.88×10^{-9}	−8.5
390	1.95×10^{-6}	2.06×10^{7}	4.86×10^{-8}	−7.3
404—407	2.70×10^{-7}	3.02×10^{6}	3.32×10^{-7}	−6.5
435	2.46×10^{-8}	2.95×10^{5}	3.39×10^{-6}	−5.5
491	3.22×10^{-9}	4.36×10^{4}	2.29×10^{-5}	−4.6
546	5.62×10^{-9}	8.45×10^{4}	1.18×10^{-5}	−4.9
576—579	2.22×10^{-8}	3.54×10^{5}	2.83×10^{-6}	−5.5



The absolute scotopic sensitivity of the eye in the ultra-violet and in the visible spectrum. Pinegin's values: *a*, for the first group of the observers (maximum in the ultra-violet); *b*, for the second group of the observers (flattening of the curve in the ultra-violet); *c*, for 9 observers (flattening of the curve in the ultra-violet); ○, Goodeve, Lythgoe and Schneider's values for 5 observers; ×, for 4 observers; ⊕, for the aphakic eye

The absolute scotopic sensitivity in the ultra-violet is subject to considerable individual fluctuations due to the fact that some of the observers show a maximum sensitivity at 334 mμ (figure, *a*), while in others there is flattening of the curve within the region of 334—365 mμ (figure, *b*).

In most of the observers the value S_{365} varies in our measurements and in those of the authors cited within about the same range, and for 2 observers on either part the respective values of sensitivity are similar. As to the mean value of S_{365}, the authors put it much below the mean for the 1st or 2nd group, or for all our observers (figure, *a* and *c*). If we were to exclude from the authors' data those pertaining to a middle-aged observer showing low eye sensitivity, then the mean value of S_{365} would be very close to the mean for all our observers (figure, *c*); it would even coincide with the mean value for the 2nd group of observers (figure, *b*).

The absolute scotopic sensitivity at 546 mμ given by the authors is on the average 2.5 times that obtained by us (figure, *c*). The threshold retinal illumination in their experiments was, accordingly, about 35 000, while in ours it was near 85 000 $\frac{\text{quant}}{\text{sec. mm}^2}$.

This discrepancy may be put down to the difference between the areas of the image on the retina. In our case the latter made up 8.8×10^{-3} mm², whereas in the measurements of the authors it was 4.2×10^{-1} mm². Owing to this, the retinal illumination should, according to the data by Gassovsky, Khokhlova and Burago ([3]), in the latter case be 12.5 times smaller than in our case. The essential difference in adaptation (1 hour in our case against 10 minutes with the authors cited) might have compensated for this discrepancy up to 2.5 times. Because of this discrepancy between the sensitivities the mean value of S_{546}/S_{365} made up in our case 4000, while in the case of the authors cited (without the observer showing low sensitivity) it was 10 000.

The results of the measurements of absolute scotopic sensitivity of a normal eye in the ultra-violet and visible spectrum, obtained by the named writers, are in satisfactory agreement with our results which they go well to support. As it should be expected; the absolute scotopic sensitivity of the aphakic eye was found to be at 365 mμ the same as at 546 mμ (figure, *a*, *c*). This fact in particular confirms the measurements of light fluctuation made by S. I. Wawilow, including the presence of a maximum of the retinal sensitivity at 3800 Å ([4-11]).

According to the authors cited, the sensitivity of the aphakic eye is twice that of the normal one, which is accounted for by the different areas of the image on the retina (0.71 against 0.42 mm²) and of the pupils (from 50 to 20 mm²). Owing to this, the retinal illuminations of an aphakic and a normal eye should, according to the data by Gassovsky, Khokhlova and Burago ([3]), exhibit the very relation observed (2 : 1). The authors consider 309 mμ to be the limit of vision for a normal, and 298 mμ, for an aphakic eye. We succeeded, however, in measuring not only the scotopic, but also the photopic sensitivity of a normal eye at 302 mμ ([1]).

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CHEMISTRY

ON THE PROBLEM OF MANUFACTURING HIGH-STRENGTH GYPSUM

By P. P. BUDNIKOV, Corresponding Member of the Academy

The problem of manufacturing high-strength gypsum and its utilization in rapid-rate building construction has at present become one of exceedingly vital importance. Randell and Dailey (1) proposed a method for manufacturing high-strength gypsum by treating natural gypsum with steam under a pressure of 1.2 atmospheres (117° C) followed by drying it in a rotary kiln at a temperature above 100° C.

F. T. Sadovsky and A. S. Shklar (2) manufactured high-strength gypsum in one apparatus—the vertical boiler (dampfer). The crushed gypsum stone is at first heated with steam or air (60—90° C) during half an hour, then it is treated with steam under a pressure of 1.3 atm. (124.5° C) for about 8 hours with a drainage of condensation water every 15 minutes. Then the dampfer is blown out first with dry steam (140° C) for half an hour, and afterwards with hot air (160—180° C) during 4—5 hours. A characteristic feature of the semihydrate thus produced is its crystalline felted structure. Upon crushing such gypsum requires for slaking only 30—35 per cent (instead of the usual 65—70 per cent) and acquires high strength during short periods of setting. Data of physical-mechanical tests obtained by the author (according to «OST») on high-strength gypsum with a water-gypsum factor of 30 per cent are tabulated below (the gypsum was obtained from the Building Trust at Ufa).

Time of tests	Temporary tensile strength, kg/cm²	Temporary compression strength, kg/cm²
After 1 hour .	28.3	164
24 hours	24.0	174
» 7 days .	Above 65*	394

* In tensile strength tests the specimens did not collapse under a load of 65 kg/cm².

An essential drawback of the high-strength gypsum manufactured by the above method is its rapid setting (beginning in 2—3 min., ending in 5—8 min.), which is accounted for by the presence in the finished product of a small amount of non-dehydrated gypsum.

Experience has shown (as realized by the Building Trust at Ufa on the suggestion of P. P. Budnikov, A. V. Kuper and V. A. Vorobiev) that no preliminary

heating of gypsum rubble is required. After treating the gypsum with moist steam under a pressure of 1.3 atm.; instead of drying with hot air from special calorifers, it is dried with hot smoke gases from fireplace steam boiler (220—240° C) for 3—4 hours.

It is known that bihydrous calcium sulphate upon heating within the range of 120—128° C, losing 1.5 molecule of its water of crystallization in a moist atmosphere, is recrystallized, forming hexahedral prismatic (pseudo-hexagonal syngony) crystals. According to Winchell (4), the specific gravity of the semihydrate is 2.55. The optic sign is positive. $N=1.55$. Refractive index 0.02 or slightly higher. Such an acicular semihydrate acquires a silky lustre, somewhat resembling the variety of bihydrous calcium sulphate known by the name of selenite. An essential difference from the latter of the semihydrous sulphate, in addition to the optical properties, is the absence of a definite orientation of crystals, resulting in a felted structure.

The minimum quantity of water for the formation of the crystalline semihydrate is a part of the water of crystallization evolved upon heating gypsum above 60° C. Important factors are the time and pressure necessary for a complete recrystallization. Investigations have shown that time and pressure may vary within a rather wide range (from 7—8 hours at 1.3 atm. up to 3 hours at 8 atm.). The structure

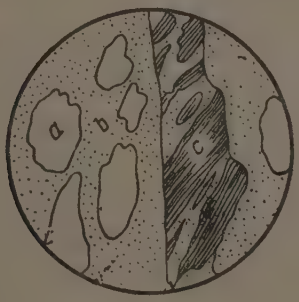

Fig. 1

Fig. 2

of the semihydrate thereby produced is quite identical in the two cases. A description of the natural gas and semihydrate produced by the two methods is given below.

The gypsum from the Polesny village; Sterlitamak region, is a rock with a non-uniform structure. The groundmass consists of fine-grained snow-white very compact gypsum (alabaster) and a thin-flaxy light-grey one. It contains frequent accumulations of colourless secondary coarsely crystalline laminated gypsum (gypsum spar). The crystals of the latter attain a length of 2.5—3 cm. with a width of 0.5 to 1 cm (Fig. 1).

The semihydrate produced from this gypsum by the method described in outward appearance presents a very uniform rock light-grey in colour with a silky lustre. It consists exclusively of colourless transparent acicular crystals. The aggregates of acicular crystals are oriented in different directions, producing the typical felted structure of the crystalline semihydrate. The length of the acicular crystals ranges from tenth fractions up to 10—15 mm (Fig. 2).

The gypsum from the village of Chesnokovka, Ufa region, is a gypsum rock of a non-uniform structure. It consists mainly of a compact fine-grained snow-white gypsum, alternating with greenish-grey fine-grained gypsum. The latter often shows evidence of leaching. Large laminated crystals are absent.

The same gypsum steamed in an autoclave during 6 hours at 6 atm. in the fracture is shown to be a product with a felted structure. The acicular crystals are colourless, transparent, with a characteristic silky lustre. Hollows on the surface

of the fragments are filled with a felted delicate crystalline mass (very fine acicular crystals). In the fracture there are observed caverns and small pores with clayey films (a result of leaching of natural gypsum). The mechanical strength is high (after 24 hours the compression strength is 133 kg/cm²; after 7 days; 280 kg/cm²).

In the gypsum of Kurochkina Gora (district of the town of Ufa) the groundmass consists of snow-white fine-grained compact gypsum (alabaster). Greenish-grey fine-grained gypsum is found in a subordinate amount. In some areas there are accumulations of secondary coarsely laminated gypsum spar. There are many pores and caverns with distinct traces of leaching of the rock and secondary crystallization (laminated crystals). The rock is weathered to a considerable degree.

The same gypsum converted by treatment into a crystalline semihydrate at the Ufa works of the Building Trust, is quite uniform in structure and presents a slightly crystalline semihydrate of a light-grey colour with a silky lustre. On the surface of the fragments in the hollows there is a delicate felted mass of very fine acicular crystals. In the fracture it is a compact finely crystalline mass consisting of aggregates of very small finely acicular crystals. The length of individual crystals does not exceed 1—1.5 mm. The aggregates of acicular crystals are oriented in different directions; as a result of which a finely fibrous compact felted structure is observed in the fracture. The author has investigated also semihydrates; produced by calcination from the above listed gypsum rocks.

The semihydrate produced by calcining bihydrous gypsum at 170° C is a uniform farinaceous mass consisting in the main of very small earthy aggregates and a fine pulverulent component. Fragments retaining a crystalline habitus are absent.

The investigations of the crystalline semihydrate produced by different means enable the conclusion to be drawn that the increased mechanical strength of this gypsum binder is caused by the structure (acicular prismatic crystals) retained after mixing with water. The microscopic investigations of the crystalline semihydrate mixed with water have shown that such a gypsum consists of fragments of acicular crystals; arranged at random, among which there are newly formed druses and individual acicular crystals of bihydrous gypsum.

Thus, in the set gypsum the structure remains felted; which undoubtedly causes an increase in the mechanical strength of the product. The gypsum produced by calcination or boiling in boilers yields a non-crystallized semihydrate. Such a semihydrate after mixing with water and setting presents a mass with an earthy structure now more and now less fine-grained, depending on the fineness of grinding. A part of the calcium sulphate here, too, forms druses and isolated crystals. However, the quantity of the two is so insignificant that no felted structure is formed.

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PHYSICAL CHEMISTRY

THEORY OF CONCENTRATION PROCESS CAUSED BY THERMAL DIFFUSION IN SOLUTIONS

By A. MURIN

(Communicated by V. G. Chlopin, Member of the Academy, 25.VII.1943)

On describing thermodiffusion phenomena in a solution of concentration n the temperature gradient is usually supposed to create a flow of the solute proportional to the concentration and the value of the temperature gradient, $D' n \frac{dT}{dx}$. Here D', the coeffificient of thermal diffusion, depends, like the coefficient of ordinary diffusion R, upon the temperature and concentration of the solution.

If the concentration process is set up in solutions by means of the Clusius separation tube, the difference of temperature between the hot and cold wall is rather small compared to the absolute temperature. Contrary to this, the concentration, if the process goes far enough, which is practically almost always the case; varies essentially along the tube, and, accordingly, D and D' assume very different values at different points of the latter. Nor should the tube be dealt with as a whole, but its different portions must rather be considered separately unless all of the formulae presented below are to give only rough estimates.

The theory of the separation tube for liquids has been given by Debye. Debye's theory permits to follow up the concentration process in the tube when there are no reservoirs at its ends. Nor does it consider the question of the concentration phenomena in the tube when the solution is removed continuously from one of its ends.

The most simple way of furnishing the respective supplements to this theory is by using the method of Furry, Jones and Onsager (1). It may easily be shown that the transport of the dissolved substance through the cross-section of the tube is

$$\tau = Hn - (K + K_D)\frac{dn}{dz}, \tag{1}$$

where

$$H = \frac{\beta g \rho (\Delta T)^2}{6!\,\mu} \frac{D'}{D} a^3 B; \quad K = \frac{\beta g \rho \Delta T}{9!\,\mu^3 D} a^7 B; \quad K_D = aBD. \tag{2}$$

Here β is the coefficient of cubical expansion of the solution; g, acceleration of gravity; ρ, density; μ, viscosity of the solution; ΔT, temperature difference between the hot and cold wall; a, distance between the walls; aB, cross-section area of the tube. The z-axis is defined to be directed vertically along the tube.

For β, ρ and μ we take average values in a given interval of temperature and concentration.

The expressions (2) for the coefficient H and $K + K_D$ have been obtained on the assumption that the dimensionless parameter $p = \frac{D'\Delta T}{D}$ is small. If H

and $K+K_D$ are known, the conclusions of the Furry, Jones and Onsager's theory for the separation of gaseous mixtures with a low content of one of the components ($c_2=1-c_1\cong 1$), may all be applied as well to the concentration process in solution within a separation tube, by putting $c_1=n$ in the formulae of those authors.

They have left, however, unsolved the problem of the concentration process of the rare component when the separation tube is provided with reservoirs of arbitrary dimensions.

In this case

$$(n_u-n_a)\,v_u=-(n_0-n_a)v_0=\frac{n_a(e^{2AL}-1)}{\frac{1}{v_u}+\frac{1}{v_0}e^{2AL}}\left(e^{\frac{H}{1-e^{2AL}}\left(\frac{1}{v_u}+\frac{1}{v_0}e^{2AL}\right)t}-1\right). \qquad (3)$$

Here n_a is the initial concentration of the solution; n_u, the concentration in the lower reservoir; n_0, the concentration in the upper reservoir; v_u and v_0, the volumes of the respective reservoirs; L, the length of the working portion of the tube; t, the duration of the experiment.

For computing the concentration ratio at the ends of the working portion of the tube under continuous and slow removal of the concentrate, one may use the respective formula of Furry, Jones and Onsager.

In our notation it reads

$$\frac{n_u}{n_0}\approx\left(e^{-2AL}+\frac{v}{H}\right)^{-1}, \qquad (4)$$

where v is the volume of the concentrate removed in unit time $\left(\frac{v}{H}\ll 1\right)$.

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PHYSICAL CHEMISTRY

ON THE VELOCITIES OF DETONATION OF NITROGLYCERINE AND NITROGLYCOL

By J. B. CHARITON and S. B. RATNER

(Communicated by N. N. Semenov, Member of the Academy, 7.VIII.1943)

1. During a search for the limiting diameters of the glass tubes at which the detonation of the inclosed liquid nitro-ester is still feasible, carried out by J. B. Chariton and N. A. Jusephovich in 1939 (unpublished), it was found that within the tubes with the inner diameter of 2 mm or more the detonation of nitroglycerine, nitroglycol or methylnitrate might be effected with the aid of a detonator No. 8*, the detonation coming to an end after its having been propagated through a length of about a hundred diameters.

In order to find out whether there was an abrupt stopping of detonation or a gradual damping we have taken advantage of the photographic method of measuring the velocity of detonation.

It was the more desirable, since the data in the literature on the velocity of detonation of liquid nitro-esters have hitherto been very uncertain. In the numerous literature on the detonation of nitroglycerine the feasible values of the velocity of its detonation are given in the range from 0.65 to 9 km per sec.; the most frequent values are those in the ranges 1—2 km per sec. and 6—8 km per sec. We succeeded to find out only two allusions to the velocity of detonation of nitroglycol: Naoum and Bertmann (1) found 8 km per sec., and Stettbacher (2) asserts that liquid nitroglycol «detonates almost invariably with the same lower velocity» (page 65).

The existing explanations of the diversity in the velocities of detonation (the effects of viscosity, density, bubbles of air, the state of aggregation, etc.) are not in agreement with the whole of the experimental data. The experimental data are greatly at variance themselves.

2. We have studied the velocity of detonation of liquid nitroglycol in glass tubes of various diameters (from 1.7 to 25 mm) from 10 to 100 cm long. The explosion in the principal series of the experiments has been effected by means of detonator No. 8. The velocity of detonation has been measured by taking photographs of the flame upon a revolving drum. The tube with nitroglycol was fixed during the runs upon a tin-plate carrier (0.4 mm thick) mounted on a vertical wooden plank.

The tests have shown that the velocity of detonation of nitroglycol may assume two values, viz., 1.8 ± 0.2 km per sec. or 7.5 ± 1 km per sec. The experimental errors indicated are due to inadequate circumferential velocity of the photographic film (below 30 m per sec.). Display of the higher or of the lower velocity is of a statistical nature; nevertheless it follows from the experiments that in the wider

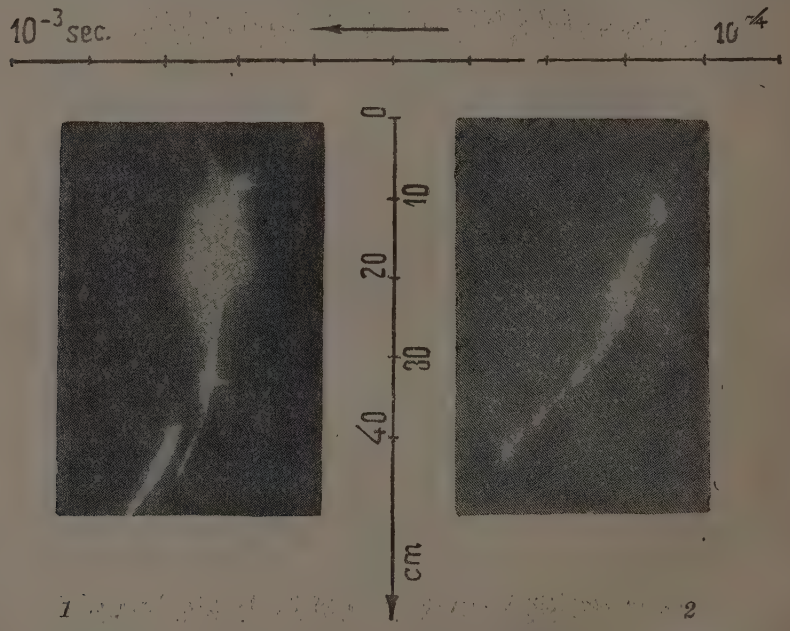
* Detonator No. 8 contains 0.5 g of mercury fulminate and 1 g of tetryl.

tubes the detonation may expand with either the higher or the lower velocity (preferentially with the higher one), whereas in the narrower tubes the detonation always proceeds with the lower velocity. The boundary between the wider and the narrower tubes depends upon the nature of the initiator and the material of the casing.

Control tests with nitroglycerine gave the same results as those with nitroglycol. The data in the literature differ from ours in considerably greater scattering, exceeding the limits of the experimental errors. The cause of that fact shall be referred to below.

3. The experimental results have shown that the detonation stopped abruptly after it had propagated through a length of a hundred or more diameters.

The photographs of propagation of the detonation in the narrow tubes register an invariable (lower) velocity of detonation and not damping, but abrupt stopping



of it, since the velocity of detonation (the decline of the curve) remains constant through the whole interspace of its expansion.

In the case of the tubes of 5 mm or more in diameter no stopping of the detonation has been observed through the length of 1 m even, when the detonation was going on with the lower velocity.

4. We have made an attempt to stimulate the higher velocity of detonation in the narrower tubes by coupling them with the wider ones and initiating detonation within the latter. The experiments gave positive results exhibiting a constant velocity of detonation independently of the width down to the diameter of 2.7 mm. There is an analogous phenomenon in the reverse case: initiation of detonation in the narrower tubes leads to its consequent propagation in the wider tubes with the identical lower velocity.

5. When an attempt was made to urge the rapid detonation from the wider tubes into narrow ones (about 2 mm) (figure, *1*) a remarkable fact of the sharp alteration of the velocity of detonation has been discovered, viz. a sharp change from the higher to the lower value. The phenomena have been repeatedly observed and

proceeded as follows: the detonation propagated with the higher velocity through the wider tube, entered the narrower tube with the same velocity and remained there unaltered for some length; then the velocity sharply dropped to its lower value; this latter remained constant through certain length and then the detonation stopped.

This result is a most convincing evidence that the two groups of velocities of detonation are discrete.

6. In two cases we were able to observe the propagation of flame in nitroglycol with a velocity of $\sim$0.7 km per sec. (figure,2), which is analogous to the result D=0.65 km per sec. obtained by Comey ([3]) with nitroglycerine. It took place in our experiments instead of the stopping of the slower detonation in narrower tubes (3.3 and 4.0 mm) and had not the nature of damping, but occurred abruptly as in the case described in § 5.

The facts set forth above encourage the conjecture that the wide range of values reported in the literature for the velocity, passing the limits of the experimental error, is in many cases due to the sharp change of the speed of propagation of the detonation from one value to another. This circumstance may pass unobserved when an average value of the velocity through all the length of the charge is measured.

Conclusions. 1. There exist two (or three) discrete groups of velocities of detonation of nitroglycerine and nitroglycol, the higher of which can sharply change into the lower.

2. The probability of development of the higher velocity increases with the diameter of the tube.

3. The propagation of detonation through narrower tubes takes place with invariable lower velocity; the detonation is abruptly stopped after it has propagated through a length of a hundred or more diameters.

4. Rapid propagation of detonation may be stimulated in the narrower tubes by coupling them with the wider ones and initiating detonation within the latter.

5. On passing from wider tubes into very narrow ones the rapid detonation changes sharply to the lower value after having propagated through some short length.

6. The propagation of the slower detonation may from unknown reasons be suddenly changed to unstable propagation of flame with the velocity of 0.7 km per sec. which has not, apparently, the character of a detonation any longer.

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PHYSICAL CHEMISTRY

ADSORPTION FROM SOLUTIONS AT HIGH PRESSURE*

By A. M. ROSEN

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While the influence of pressure on adsorption from the gaseous phase has been studied both theoretically and experimentally [1, 2], no one appears as yet to have undertaken to investigate the adsorption from solutions at high pressure.

The author has made an attempt on this line by taking the classical case of adsorption of acetic acid by activated charcoal.

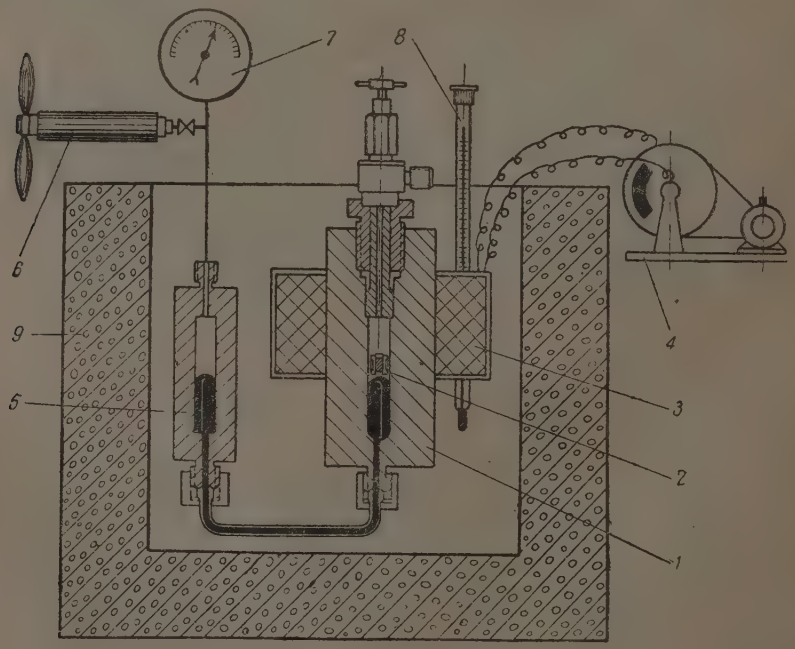

Fig. 1

The set-up used in this investigation is represented schematically in Fig. 1. The acetic acid in autoclave *1* was pressed by mercury. As the hydraulic press *6*

* This work was accomplished in May 1941. Its publication has been delayed by purely external circumstances.

(2500 atm.) was run on oil, a buffer column 5 was inserted. The adsorbent was placed in stirrer 2 which was driven by electromagnet 3 provided with interrupter 4. The autoclave with the buffer column were placed in thermostat 9 (with transformer oil) which was provided with a screw stirrer, two electric furnaces and a toluol thermoregulator. Although the walls of the autoclave were of considerable thickness (outer diameter, 120 mm; inner diameter, 30 mm; material, non-magnetic steel ЭИ-1-Т) the vertical path of the stirrer attained 30 to 40 mm. The samples were taken at constant pressure and after heating titrated with 0.01 *n* barite.

Control tests have shown that such factors as the dissolution of mercury or of the ring of the stirrer in the acid have no influence of practical importance. Neither

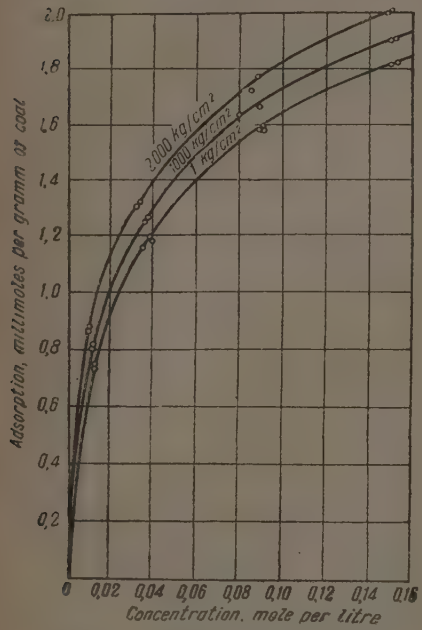

Fig. 2. Isotherms of adsorption of acetic acid by activated charcoal at 25° C

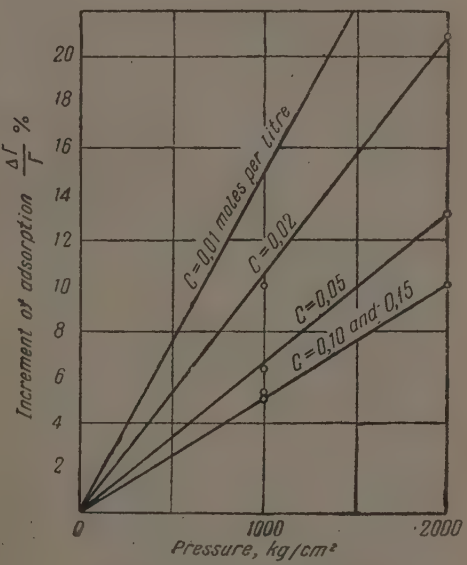

Fig. 3. Relationship between adsorption and pressure

has it the adsorption by the walls of the autoclave. The reversibility of the adsorption has also been proved. Three adsorption isotherms were taken: at atmospheric pressure, at 1000 and 2000 atm. (at 25°C). The results are represented in Figs. 2 and 3. As may be seen from these figures, the adsorption grows with pressure. On the portion of 1 to 2000 atm. the course of the curves is nearly linear, though there are reasons to suppose that no such relation takes place in a higher range of pressure. The increase of adsorption with pressure is the higher, the lower the concentration of the solution. The 1000 and 2000 atm. isotherms are seen in Fig. 2 to be of the same type with the 1 atm. isotherm. It may be remarked that none of them conforms to the equation of Freindlich.

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GEOLOGY

THE UPPER JURASSIC OF THE DONETZ RANGE

By L. LUNGERSHAUSEN

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The present paper is a continuation of a series of papers by the same author, dealing with the stratigraphy of the Donetz Mesozoic (1). A brief review of novel data on the stratigraphy of the Upper Jurassic is given below.

As shown previously, the Middle Jurassic of the Donetz range terminates with river and deltaic deposits of the so-called Kamenka series. The latter is transgressively (at some places unconformably) overlain by marine Upper Jurassic deposits, represented (as distinguished from the Middle and Lower Jurassic) mainly in the limestone facies. The stratigraphic range of the limestone formation has been elucidated by the studies of A. A. Borissiak and V. Nalivkin; the lowermost portion of the formation has been found to belong to the Upper Callovian; and the upper, to the Kimmeridgian. To the Kimmeridgian have also been referred the irregular stocks of coral reefs connected with the upper part of the limestones (the fauna of the reefs has not been subjected to a special study). The foot of the limestones is of different age at different places; in the most complete sections (Protopopovka, Zavodskie Khutora) the lower arenaceous limestones were found to contain, along with Upper Callovian ammonites, elements of Middle Callovian fauna (*Stephanoceras coronatum*, etc.); however, because of the subordinate importance of the latter there were no grounds for separating out an independent stratigraphic horizon.

Stratigraphy. The Upper Jurassic deposits are subdivided into two series: the lower, Kremenetz series composed of marine limestones, higher up of lagoonal-marine and lacustrine deposits, and the upper, Zavodskaya series separated from the preceding one by a surface of a great erosional and tectonic unconformity. In the numerous sections in the banks of the North Donetz and its tributaries, the limestone beds are underlain by thin packs of ferruginous sandstones, sometimes with oyster beds and coral growths (*Stylina solida* M'Coy, etc.).

In the basin of the Britai river (village of Nelyubovo) the lower arenaceous limestone with *Quenstedticeras lamberti* and other Upper Callovian forms rests on yellow-brown marlaceous sands and sandstones with intercalations of ferruginous oolite, containing a poor but characteristic fauna: *Kepplerites calloviensis* Sow., *Kepp. duncani* Sow., *Cosmoceras* sp. (ex. gr. *jason*?), *Oxytoma inaequivalvis* Sow. var. *borealis* Boriss., *Pecten* ex gr. *fibrosus* Sow., *Ostrea* sp. (cf. *vollata* Etal.), *Gryphaea* ex gr. *dilatata* Sow., *Rhynchonella* sp., *Serpula* sp., etc.

The Middle (and in part possibly also Lower) Callovian age of the forms listed leaves no room for doubt (in England *Kepp. calloviensis* is found as low as the *Macrocephala* beds), and thus the presence in the Donetz basin of the Middle Cal-

lovian, faunistically characterized and stratigraphically distinguishable may be considered as established.

The solution of the problem as to the age of the coral reefs is a very important task. There seems to be no convincing evidence for referring them to the Kimmeridgian. An Oxfordian age seems to be more probable. In the green clays filling pockets and hollows in the surface of the reef crags *Perisphinctes plicatilis* Sow. has been found, which is common in the Upper Oxfordian. The coral horizon is followed higher up by a characteristic series of thin-bedded limestones, alternating with clay bands, crammed with needles of *Paracidaris florigemma* Phill.; a guide form for the Rauracien of Western Europe.

Finally, what testifies of the reefs being most probably Oxfordian; is the species composing the coral fauna; namely: *Thamnastraea concinna* Goldf., *Th.* aff. *nicoleti* Koby, *Dimorphastraea dubia* From.; *Calamophyllia quadragenaria* Ratch. (sp. nov.), *Isastraea* aff. *greenhoughi* Edw. et Haime, *Is. explanata* Goldf.; to which *Epismilia* cf. *alsatica* From. et Fer.; *Mantlivaultia* sp. and others are added (determined by V. I. Rachitsky and in part by the author).

Cephalopods are concentrated mainly in the lower part of the limestone beds (they have been described by A. A. Borissiak). Characteristic of the middle portion of the beds is the abundance of *Trigonia* composing whole banks; along with forms common in the Oxfordian, Kimmeridgian and even Portlandian of Western Europe; typical representatives of a new genus (gen. nov.) are encountered here, having greatly swollen radial plications. Throughout the thickness of limestone beds, but particularly in their lower part, remains of sea urchins are found, among which mention may be made of such forms as *Paracidaris florigemma* Phil. sp., *Pseudodiadema* sp. ind., *Glypticus* cf. *hieroglyphicus* Goldf. sp., *Nucleolites scutatus* Lam., *Coellyrites* cf. *bicorata* Leske sp. and others (determined by A. V. Faas), which induce us to seek in the limestone beds an equivalent of the Lusitanian stage of the French geologists.

A cumulative section of the Kremenetz series may be represented as follows:

Middle Callovian:	1. Ferruginous sandstones with *Kepplerites calloviensis*.
Upper Callovian:	2. Arenaceous limestone with *Quenstedticeras lamberti*, in the lower part with elements of Middle Oxfordian fauna (*Stephanoceras coronatum*, etc.).
Lower Oxfordian:	3. A horizon transitionary to the Callovian: a joint occurrence of Oxfordian and Upper Callovian ammonites.
	[4. Limestone with *Cardioceras cordatum* Sow., *C. excavatum* Sow., *C. quadratoides* Nick., *Aspidoceras faustum* Bayle, *Peltoceras arduennense* d'Orb., *P. eugenii* Rasp., and others.
Upper Oxfordian:	5. *Trigonia* limestones.
	6. Coral reefs.
	7. Oolite limestones and marl with *Paracidaris florigemma*, *Pentacrinus* and *Perisphinctes plicatilis*.
Lower Kimmeridgian:	8. Limestone with *Nerinea ursicinensis* and other gastropods.
Kimmeridgian:	9. Lagoonal variegated clays.
	10. Lacustrine clays, loams and fine sandy loams.

The thickness of the limestone formation (beds 1—8) does not exceed 40 m; that of the lagoonal (9) and lacustrine (10) series of the Kimmeridgian attains in the most complete sections 55—75 m.

The Zavodskaya series may be referred to the Titonian and partly compared with the Titonian continental and lagoonal deposits of the Caucasus. It is represented by a layer of white kaolinic unstratified sands and loose sandstones stuffed with huge rollers and blocks of variegated clays formed of eroded Jurassic strata. According to their genetic type, such deposits may rather safely be related with the proluvium.

The Zavodskaya series lies on various horizons of the Jurassic: on lacustrine Kimmeridgian loams (Protopopovka), on lagoonal clays (Izyum, Kramatorsk); on Oxfordian limestones (Svyatogorsk), on Middle Jurassic continental sandstones (Yaremovka), on Bathonian and Bajocian clays (Mayaki), on the Liassic (Verolyubovka), passing even onto the Triassic (Serebryanka, Shipilovka) and the Palaeo-

zoic (northern marginal part of the Donetz range). From above the Zavodskaya series is transgressively overlain by glauconitic sandstones of the Albian-Cenomanian.

Thus, the boundary of the unconformity corresponding in the Donetz range to the young Cimmerian movements (Andic phase) does not pass at the base of the Cretaceous formation, but lower, at the base of the continental Zavodskaya series, lying directly above the lagoonal and lacustrine deposits of the Kimmeridgian.

Palaeogeography. The beginning of the Upper Jurassic transgression refers to the end of the Lower Callovian. The sea penetrates to the lowest areas of the north-western marginal part of the Donetz range, vast areas of land being left non-submerged, as e. g. old Palaeozoic projections (domes) between Slavyansk and Izyum.

The latter were submerged only in the Oxfordian (Slavyansk) and even in the Kimmeridgian (Dovghenkoye). The geography of the sea was complicated, the shores were highly dissected, the bathymetric conditions of the basin itself were highly variable. The diversity of the geological composition of the surrounding dry land, due to the complicated outlines of the ancient tectonic relief, caused the diversity of the petrographic composition of the sediments accumulating in the different parts of the basin: on the slopes of Palaeozoic islands, on the one hand; and in deep depressions, on the other. Thus, the limestones clothing the northern slope of Korul island, are distinguished by a high hypersthene content (100 per cent of the heavy fraction), while at other places hypersthene is absent or occurs but rarely; in the limestones of Izyum and Kamenka there is a large amount of zircon (up to 90 per cent of the heavy fraction), as well as of tourmaline, rutile, partly garnet, epidote, disthene, etc.; the limestones of Valeryanovka (Britai river) are distinguished by the presence of sillimanite; there is also a large amount of zircon, rutile, tourmaline, garnet, staurolite, partly disthene, etc.

The advance of the shore line of the sea in the process of its consecutive transgression may as yet be reproduced in the most general outlines only. The original sea had the shape of a narrow bay, of almost latitudinal (north-eastern) direction; stretching from the village of Nelyubovo, as it appears, along the ancient bed of the Britai river and the Bereka river, to Protopopovka on the North Donetz. During the following (Upper Callovian) age the sea extended over a wider area; bathing the slopes of the Druzhkov-Konstantinov anticline (the Mayachka river).

During the Oxfordian almost the whole of the north-western marginal part of the range was submerged by the sea; the Palaeozoic islands reduced in size or converted to shoals. In the north-west the sea extended far into the Dnieper depression, reaching Pereschepin. By the end of this age coral reefs were formed. The latter were of the nature of a low subaqueous barrier, in any case they were connected in chains parallel to the sea shore. The main ridge of reefs seems to have extended from Protopopovka to Izyum, Kamenka and Sukhaya Kamenka in a sublatitudinal (WNW) direction typical of the Donetz range, along the northern foot of the Slavyansk, Korul, Kamyshevakha and Petrovsk domes, which at the moment of reef-building represented small islands or shallow-water portions of the sea.

The coral reefs of the Britai river were either connected in an arch-like fashion with the Izyum-Protopopovka reef barrier, leaving aside the Petrovsk dome, along its eastern slope or else formed a second chain parallel to the first one, and running towards the Mayachka river (the coralline limestones of the town of Kramatorsk).

In the Kimmeridgian there begins a regression of the sea. The marine conditions of the basin are replaced by lagoonal ones. The limestones pass upwards into variegated clays with a more restricted development than the deposits of the marine facies.

At places; the lagoonal clays have a finely foliated lamination; caused by an alteration of clastic material of a different mechanical composition—more clayey (tenth fractions of a millimeter thick) or more sandy bands, each band ending in its upper part in a very thin ferruginous crust (traces of a peculiar subaqueous weathering).

Such changes in the nature of sediments might have been associated with seasonal changes in the conditions of closed or half-closed lagoons and lakes and presented good opportunities for geochronological observations. The lagoonal deposits pass upwards into lacustrine ones; having a still narrower (spotty) distribution than the sediments of lagoons. A vast lake stretched from Protopopovka to Spevakovka, probably without reaching Izyum. The same tectonic movements which caused the rapid regression of the sea; the replacement of marine conditions by lagoonal ones; the transformation of lagoons into a system of small lakes,—must have produced the phenomenon of a subaqueous sliding of plastic clayey sediments on the bottom of lagoons and lakes; as a result of which rather complicated deformations were produced, bounded by the narrow limits of a definite pack of beds. The same movements resulted later in the formation of wide, gently sloping folds; soon eroded and buried under the mantle of Titonian proluvium.

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PHYSIOLOGY

ON THE CHEMORECEPTOR FUNCTION OF SUPRARENAL GLANDS

By A. D. ADO and V. N. SMIRNOV

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Our knowledge as to the structure and functions of the receptor apparatus of the suprarenal glands is still lacking sufficient clarity. In 1894 Dogiel (1) described from the adrenal medulla of dogs, cats and rabbits nerve endings which seemed to him to remind Messner's corpuscles, or sexual sense-cells. Such nerve endings are now given the name of mechanoreceptors. Pines and Narovchatova (2) observed in the perivascular connective tissue of the medulla of subrenal glands of the same animals cone-like nerve endings which they believed to be receptory in nature.

The existence in the tissue of the suprarenal gland of chemoreceptor apparatus may be assumed on the ground of experiments by Averianov and Medvedeva (3) jointly with Smirnov (4). According to these writers, the introduction of adrenaline into the tissue or vein of a perfused suprarenal gland of a dog, brings about a prolonged rise of blood pressure, which is apparently of reflectory origin.

The present note contains the results of our investigation of the chemoreceptor function of the suprarenal gland of the dog in response to various stimuli.

The suprarenal gland was perfused in our experiments with oxygenated Tyrode solution through the *arteria phrenico-abdominalis*, the rest of arterial vessels of the gland being ligatured. *Arteria phrenico-abdominalis* branches off the abdominal aorta directly under the body of the suprarenal gland; at a distance of 3—5 mm it gives off two branches towards the adrenal tissue. In some cases there occur supplementary branches running towards the suprarenal gland, departing from a lower point of the course of the artery. The main trunk of the artery gives off two small branches more towards the suprarenal adipose tissue, and divides into two chief branches, one towards the diaphragm, and the other, towards the muscles of the abdominal wall. The perfusion cannula is usually inserted into this latter branch.

The main trunk of the artery is ligatured near its very point of departure from the aorta.

Moreover, all branches of this artery, as well as the rest of adrenal arteries, are also ligatured. The tissue of the suprarenal gland being rich in anastomoses, it was found possible to effectuate the perfusion through the small branches of the *arteria phrenico-abdominalis* referred to above. The connexion between the suprarenal gland and body of the dog was through the *n. abdominalis* and the nerve stemlets, binding the suprarenal gland with the ganglia of *plexus solaris*.

The experiments were run on the left-hand suprarenal gland, that from the right side being removed. As material for all the experiments served dogs. The substance to be tested was introduced into the perfusion liquid.

The following substances were tested: 1) adrenaline 1 : 1000, 0.5 cm³; 2) benzedrine 1 : 1000, 0.5 cm³; 3) ephedrine 1 : 100, 1—2 cm³; 4) histamine 1 : 10 000, 0.5 cm³; 5) acetylcholine 1 : 10 000, 0.5 cm³; 6) cocaine 1 : 100, 0.5—1 cm³; 7) pure normal horse serum in normal dogs and dogs sensibilized to it, 2—5 cm³.

The dogs were made sensitive by injecting them subcutaneously with 0.2 cm³ of normal horse serum per 1 kg of life weight. The experiments were started 18—25 days upon this procedure. Record was made of the blood pressure in the *carotis*, and in some experiments of the respiratory movements, of the volume of the spleen and of the paw.

The results of our experiments are summed up in the table adjoined.

Substance	Reaction	Note
Adrenaline 1:1000, 0.5 cm³	Blood pressure increased for 30″—5′ (30 tests)	In normal dogs or dogs made sensitive with horse serum
Do	Blood pressure reduced for 5—30″ (5 tests)	In weakened dogs by the end of the test, upon bleeding or in shock state
Benzedrine 1:1000, 0.5 cm³	Blood pressure unaltered	Normal dogs
Ephedrine 1:100, 1—2 cm³	Do	» »
Histamine 1:10000, 0.5 cm³	Blood pressure increased for 10—30″ (3 tests)	» »
Acetylcholine 1 : 10000, 0.5 cm³	Blood pressure reduced for 5—10″ (2 tests)	» »
Cocaine 1:100, 0.5—1 cm³	Blood pressure reduced for 10—30″ (2 tests)	Normal dogs and dogs made sensitive
Normal horse serum, 2—5 cm³	Blood pressure unaltered	Normal dogs
Do	Blood pressure increased (14 tests)	Dogs made sensitive
»	Blood pressure unaltered (6 tests)	Do
»	Blood pressure reduced (4 tests)	»

As may be seen from the table, the introduction of adrenaline in the flow of the perfusion liquid resulted in most of the tests in a rather prolonged rise of arterial blood pressure. The reflex was attended by a contraction of the spleen (see figure).

No essential alteration in the volume of the paw was usually observed. Neither were there any appreciable changes in the respiratory movements. Cutting of the *n. vagi* on the neck, or cutting of the synus nerves, or the two operations practised simultaneously, did not remove the vasomotoric reflex described.

In a small number of experiments the introduction of adrenaline in the flow of the perfusion liquid reduced blood pressure in the *carotis* instead of raising it.

The phenomenon was commonly observed against a background of low blood pressure in the great circle, or of shock conditions. In number of cases we observed it also towards the end of the experiment, after prolonged perfusion and survival of the suprarenal gland, under these, not quite physiological conditions.

The variation in the reflectory responses to adrenaline from the adrenal chemoreceptors may possibly be underlain by different mechanisms. The suprarenal gland may be supposed to possess two kinds of chemoreceptors, viz. such as produce hyper- or hypotonic reflexes.

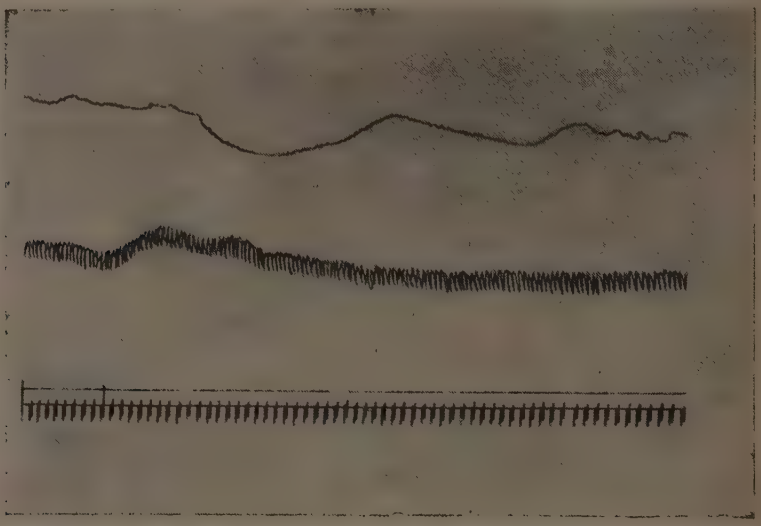
The excitability of the two kinds of receptors may vary at different periods and under different conditions of survival of the organ subjected to perfusion, and thus determine the nature of the ultimate total response.

It may also be that the suprarenal gland contains but one kind of chemoreceptors, «hypertonic» ones, their stimulation producing invariably a «tonic» vasomotoric reflex.

Under certain conditions (prolonged perfusion, shock) at the concentration applied adrenaline produces a toxic effect upon the receptor apparatus of the suprarenal gland, reducing the intensity of the reflex referred to above. It may, however, be admitted that both of these assumptions be true.

In order to analyse this problem; we introduced in the perfusion liquid anaesthetic substance, viz. 1 per cent cocaine. This procedure resulted in a certain drop of blood pressure.

After the cocaine is washed off the suprarenal gland with Tyrode's perfusion liquid, blood pressure is restored. Anaesthesia of the chemoreceptors of the supra-



Dog. Upper curve, volume of spleen. Lower curve, blood pressure in the femoral artery. Note: Introduction of 0.5 cm^3 of adrenaline 1 : 1000 into the flow of perfusion liquid. Time, 1 sec.

renal gland is thus attended by a «hypotonic reflex» bringing out the existence of a tonic vasomotoric reflex, actually suppressed by cocainization.

Benzedrine produced in our experiments no effect upon the chemoreceptors of the suprarenal gland. Ephedrine also proved poorly active. Histamine brought about a pronounced hypertonic vasomotoric reflex. Acetylcholine called forth a slight decrease in the blood pressure within the great circle.

By introducing normal horse serum into the perfusion liquid no alteration of blood pressure was obtained in the case of non-sensibilized dogs. With dogs previously made sensitive; the serum; when introduced into the adrenal vessels; mostly produced a slight hypertonic reflex. In some cases, however, there was hypotonia, or no changes of blood pressure at all (see table).

The fact that hypertonic reflexes have been obtained from adrenal chemoreceptors by introducing into the vessels the gland substances that cause sharp hypotonia when introduced into the general current of blood circulation (histamine, horse serum) points to the special defensive rôle of those reflexes in helping the organism to overcome circulation disturbances under shock conditions.

It has been known long since that the removal of the whole suprarenal gland, or of its medulla, still aggravates the developing shock phenomena (Swingle, Rudolf, Rogoff, Wyman and others) ([5],[6]). The operation makes it also possible to produce shock in animals which otherwise defy all attempts (for example, the anaphylactic shock in rats upon removal of their suprarenal glands).

The endocrine function of the suprarenal gland is thus complemented by one more, closely related form of activity, the interreceptor function (Bykov). The reflexogenic zones of the adrenals seem to play an important part in the controlling of circulation accidents that attend shock conditions.

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MICROBIOLOGY

AGGLUTINATION OF ERYTHROCYTES BY INFLUENZA VIRUS

By A. K. SHUBLADZE and V. D. SOLOVIEV

(Communicated by N. F. Gamaleja, Honorary Member of the Academy, 14.VII.1943)

While cultivating various strains of influenza virus upon the chorion-allantois of a chick embryo, Hirst ([1-4]) became aware of the phenomenon of agglutination of erythrocytes in the blood discharged by the injured vessels of the embryo. The adhesion of the red blood globules set in as soon as the blood entered in contact with the embryo's allantoic fluid which contained influenza virus. Uninfected allantoic fluid was not endowed with the capacity of producing agglutination of erythrocytes. In the subsequent Hirst readily succeeded in reproducing this phenomenon by mixing in a test-tube washed-off chick erythrocytes with embryonic allantoic fluid of eggs infected with various strains of influenza virus.

Influenza virus, adapted to the lungs of white mice, was also found to bring about adhesion of red blood globules. On the other hand, the addition of immune antigrippal serum to a mixture of virus and erythrocytes was found to prevent the agglutination reaction. This phenomenon of inhibition appeared to be a highly specific one, taking place only in the case of interaction between erythrocytes, immune serum and a virus strain homologous with that of this immune serum. In his last work Hirst successfully applied his discovery to the study of the immunological efficiency of various antigrippal vaccines used for the immunization of extensive groups of human subjects. He thus showed by a simple and accurate method the dynamics in the increase of the immunity from influenza, the duration of immunity and its stability.

We undertook a series of experiments which; on the one hand, went to support Hirst's results, on the other hand, yielded new data.

In carrying out the agglutination reaction of chick erythrocytes according to Hirst we made use of the Moscow strain of influenza virus, adapted to the lungs of white mice. Various dilutions of the emulsion from lungs of mice affected with influenza were taken, 1.0 cm^3 per test-tube, and mixed with equal amounts of washed-off chick erythrocytes, taken in the form of a 2 per cent suspension in salt solution. After one-hour stay at a temperature of 14° C, in the first four test-tubes which contained virus dilutions 1 : 10, 1 : 100, 1 : 1000, 1 : 5000, one could observe agglutination of the red blood corpuscles, which was seen by the formation of a precipitate with sharply torn edges, and by coloured fluid over it containing small flakes of erythrocytes slowly slipping down the walls of the test-tubes. In the rest of test-tubes which contained higher dilutions of the virus; as well as in all the controls which; instead of an emulsion from lungs of mice affected with influenza, were added an emulsion of normal lungs, or of lungs infected with the virus of *typhus exantematicus*, the precipitate on the bottom was round, of clear-cut outlihe; the fluid over it was transparent, without any flakes at the walls of the test-tubes.

The specific nature of agglutination of erythrocytes by the influenza virus has been confirmed by reproducing the phenomenon of prevented agglutination with the aid of specific immune serum.

The series of test-tubes each of which contained 0.5 cm^3 of the emulsion from lungs of mice affected with influenza at various dilutions, was added per 0.5 cm^3 of hyperimmune antigrippal horse serum and 1.0 cm^3 of a 2 per cent suspension of washed-off chick erythrocytes. The controls contained a mixture of 0.5 cm^3 of virus in various dilutions, 0.5 cm^3 of normal horse serum, and 1.0 cm^3 of a 2 per cent suspension of washed-off erythrocytes. Only a single test-tube of the first series, namely, the one containing the virus in a dilution 1 : 10, showed slight agglutination, while in the rest of test-tubes there were no signs of it whatever. In the test-tubes of the second series, which contained virus and normal serum, agglutination took place in the first four dilutions of the virus.

These experiments made us convinced of the stability and specificity of the reaction; however, when comparing the agglutination titres in our test-tubes we had the idea that our estimate of the intensity of agglutination might possibly be not quite free of personal judgment. We developed therefore a more rapid and simple method for reproducing the reaction which seemed to us to secure in each separate case an absolutely objective evaluation of the degree of agglutination of erythrocytes.

Having taken a drop of the mixture used in our previous experiments (in test-tubes) we put it on a subject glass, and obtained a much better and more clearly pronounced agglutination of erythrocytes, which could well be distinguished with the aid of a magnifying glass and was also visible by an unaided eye. We then carried out a whole series of experiments in which the reaction of agglutination of erythrocytes proceeded upon subject glasses.

We took influenza virus in various dilutions; mixed a drop of it with a drop of a 2 per cent suspension of erythrocytes, and recorded the agglutination that set in, both with the help of a magnifying glass and with the naked eye. The agglutination commenced very soon, within 3—5 minutes. The titre of virus capable of producing agglutination of erythrocytes in reactions upon glass never exceeded a dilution of 1 : 5000, corresponding to the range of dilutions that had caused agglutination of erythrocytes in test-tubes.

Along with this, the virulence of the same virus was tested by infecting mice intranasally; the mice fell ill and perished from influenza infection when administered an emulsion from grippal lungs in a dilution of 10^{-6}.

The inhibitory effect of the specific immune serum upon the agglutination of erythrocytes also proved most illustrative in the experiment on subject glasses. On the one half of a glass a drop of specific horse immune serum was mixed with one drop of diluted virus and another of a 2 per cent suspension of erythrocytes; on another half, instead of a drop of the immune serum we put one drop of normal horse serum. In this mixture the agglutination reaction proceeded within 3—5 minutes, while in the mixture with immune serum agglutination failed to set in at all.

The phenomenon of prevented agglutination was brought about by immune sera in dilutions down to 1 : 64; this was in proportion to the titre of the serum tested in our experiments on neutralizing the virus of influenza on mice (Tables 1 and 2).

In case the serum used in the experiment was undiluted, or in a dilution 1 : 2; and it was mixed with a virus administered in decreasing doses; the ability of the immune serum to prevent agglutination was manifest in any dilution of the virus which had been found capable of producing agglutination of erythrocytes in the presence of a normal serum, while the reaction of absolute neutralization failed to set in until the virus was diluted to 1 : 10 000.

Being in position rapidly to perform with unmistakable results agglutination of chick erythrocytes by the virus of influenza on glass, we undertook to test the sensitivity to this reaction of erythrocytes of other animal species and human subjects. It was found that out of the twelve species of animals tested by us, an agglutination of erythrocytes as good as that of young chicks is shown also by

Table 1

Agglutination of Erythrocytes as Prevented by Virus of Influenza in 1:100 Dilution

Dilution of serum	Agglutination reaction with antigrippal serum	Agglutination reaction with normal serum
1 : 2	—	++++
1 : 4	—	++++
1 : 8	—	++++
1 : 16	—	++++
1 : 32	—	++++
1 : 64	++	++++
1 : 128	++++	++++

Symbols: ++++ positive reaction; ++ slight reaction; — no agglutination

Table 2

Dilution of serum	Mice infected with a mixture of 1:100 grippal virus with immune serum	Mice infected with a mixture of 1:100 grippal virus with normal serum
1 : 2	3/0	3/3
1 : 4	3/0	3/3
1 : 8	3/0	3/3
1 : 16	3/0	3/3
1 : 32	3/0	3/3
1 : 64	3/0	3/3
1 : 128	3/0	3/3
1 : 256	3/2	3/3

Symbols: numerator, number of mice infected; denominator, number of mice that fell ill with and perished of influenza.

adult chicks, guinea-pigs, dogs and human subjects. A lower rate of agglutination is peculiar to the erythrocytes of white rats and mice, while those of horses, sheep; foxes, cats, rabbits and frogs do not agglutinate at all. We took for our tests mostly erythrocytes from several individuals belonging to a single species, the results of our experiments being always constant.

Human erythrocytes and those of the dog, guinea-pig and adult chicks were found endowed with about the same agglutination capacity when treated with the virus of influenza. The intensity of the reaction in them is in no way inferior to the agglutination properties of the erythrocytes of young chicks. The sensitivity of guinea-pig erythrocytes is somewhat higher.

When testing the phenomenon of agglutination as prevented under the influence of antigrippal serum, this phenomenon proved to be of regular occurrence in the reactions with dog erythrocytes. Human erythrocytes showed in this case a somewhat different mode of reaction, while those of the guinea-pig yielded a varying positive effect.

In our search for the optimal conditions of the reaction of agglutination of erythrocytes, we found that at a temperature of 11—12° C the reaction set in 3 minutes after contact between the erythrocytes and the virus had been established, and was complete within 5 minutes. At 17—18° C the reaction started after 15 se-

conds and came to an end in the course of $1^1/_1$—2 minutes. The highest rate of the reaction has been observed at a temperature of 36° C. Under these conditions it was found to set in directly, and to take but one minute to be completed. At any of the temperatures tested the reactions were equally distinct.

Our subsequent work was devoted to the study of the agglutination capacity of erythrocytes when subjected to the influence of other viruses available in this laboratory. Our experiments embraced the following viruses: that of the spring-summer tick encephalitis; of the encephalitis of the silver-black fox, of the erruptive fever, of the infectious ectromelia of mice and that of the vaccina.

In none of the cases, except for the last of the viruses listed, and with none of the twelve animal species tested for their erythrocytes did we observe agglutination reaction. As to the virus of vaccina kindly put at our disposal by Prof. M. A. Morozov, with one strain positive, and with the other; negative results were obtained. A case of positive agglutination of chick erythrocytes by the vaccina virus has recently been reported by Nagler [5].

To conclude with, it should be pointed out that in our experiments on the reaction of agglutination of erythrocytes acted upon with the virus of influenza; use has been made not only of a virus adapted to mouse-lungs, but also of a virus cultivated upon the chorion-allantoic membrane of a chick embryo.

Conclusions. 1) The present work corroborates the data by Hirst who discovered the phenomenon of agglutination of chick erythrocytes by the virus of influenza, and the inhibition of this reaction by specific immune serum.

2) Our modification of the method for producing agglutination reaction by mixing the erythrocytes with the virus on a subject glass proved more rapid, simple and demonstraive as compared to Hirst's method.

3) We have found that analogous phenomena of agglutination of erythrocytes under the influence of the virus of influenza are observed not only in chicks, but also in mammals; viz. in guinea-pigs, dogs and in human subjects. The erythrocytes of white rats and mice show slighter agglutination.

4) The erythrocytes of horses, foxes, sheep, cats; rabbits and frogs are not endowed with this capacity.

5) The agglutination of human and canine erythrocytes by the virus of influenza can also be prevented by adding specific immune serum. The erythrocytes of guinea-pigs offer unconstant phenomena of inhibition.

6) The temparature optimal for the reaction of agglutination on glass is 17—20° C. Within this temperature range the reaction takes from 15 seconds to $1^1/_2$—2 minutes.

7) The rest of the viruses tested by us failed to bring about agglutination of erythrocytes, either in mammals, or in fowl, except for the virus of vaccina.

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EVOLUTIONARY MORPHOLOGY

SOME PECULIAR FEATURES OF THE FORMATION OF BALANCERS IN LARVAE OF *PLEURODELES WALTLII*

By D. P. FILATOV

(Communicated by L. A. Orbeli, Member of the Academy, 27.IV.1943)

When inquiring into the historical significance of the separate characters of animal groups, comparative morphology has up to the present time been confined to the descriptive data furnished by the investigation of the phylo- and ontogenesis of those characters; no study of the latter could, moreover, be started until the moment when the anlage of the respective character (or organ) came into being. And it was not until experiment made it clear that the anlage originates as a result of an interaction between its own material and that of some other part; or different parts of the embryo, that the scope of the investigation of the ontogenetic development of a given character became wider, embracing the whole variety of those interactions, in order to find out the regularities by which they are ruled.

We are interested here in such form-building interactions whose variations in different groups of organisms show a definite kind of succession which may be associated with a definite evolutional process. Instead of investigating the historical significance of a character or an organ, one thus becomes able to analyse the mode by which these came into being at a period preceding that of the anlage.

What may be the rôle of such an investigation in the problem of the mechanism of the evolutionary process, and what is its advantage over a study beginning with a complete anlage, has been discussed in my earlier notes ([1], [2]). In concluding the latter of them, I summed up in the following words the data of the examples discussed: «The main idea to which one is led by a comparison of the data supplied by the development mechanics and evolutionary morphology, consists in that the explanation of many processes, both onto- and phylogenetic ones, should be sought for in the more general and simpler phenomena arising in the various parts of the form-building apparatus rather than in the anlage of the organ, i. e. in those two parts of the developing embryo, the one of which yields the material for a given anlage, being subdued by the formative action of the other».

In this small study I give an example which goes to support the above statement. I carried out experiments on the morphogeny of the balancers in *Pleurodeles waltlii* and in *Triton taeniatus*. The experiment showed that the process of centralization of the balancer-forming properties of epithelium in *Urodelae*; which is leading in some groups of organisms to a total disappearance of these properties and whose existence I presumed on theoretical considerations; does actually exist. This process consists in that in some *Urodelae* (*Triton taeniatus*) the balancer-forming properties of the epithelium towards the period of the anlage of the balancers are spread all over the epithelium or at least over its greatest part.

In other *Urodelae* (*Pleurodeles waltlii*) these properties are towards the same period focused at the place of the origination of the balancers only, being absent at any other place. In the axolotl the epithelium is utterly deprived of the capacity of forming balancers, though the source of the formative action has been preserved. Its presence has been proved by grafting triton epithelium on to a spot where in an axolotl there should be formation of the balancers that do not appear in case the development is a normal one. From grafts of triton epithelium balancer-formation could also be obtained in the axolotl. Consequently, the formation of balancers was a reaction for the formative source preserved in the axolotl's head (Mangold, 1931).

The table on page 12 of ([1]) illustrates the succession of the variation of the lens- and balancer-forming capacities of the epithelium in various organisms. The table reproduces three stages of either of these properties of the epithelium; aside from the hypothetical one. In the first column, referring to the lens-forming properties, the third stage; that of a total disappearance of these properties; is unknown. Further investigations may possibly prove its existence. The second column; that referring to the data on balancer-forming properties, shows a blank place for the second stage—the reduction of the region of balancer-building properties. I think that I have succeeded in demonstrating the existence of this stage for *Pleurodeles waltlii*.

The respective work has not yet been achieved for lack of material. The experiments consisted in removing the epithelium from behind the eye in two stages, both in *Pleurodeles waltlii* and *Triton taeniatus*. The younger stage was taken directly upon the closure of the neural crest, the latter, as soon as the tail bud is manifest. Behind the eye, somewhat below its level, I removed a piece of epithelium of about the same size as the eye area, and allowed the edges of the epithelium to close over the wound.

In this way instead of the area of epithelium that should have served for the formation of the balancers the wound was covered with the epithelium that previous to the operation lay near that area. At the early stage the result of the experiment was identical for the two triton species: the balancers formed in the two cases. This should be taken to mean that at the younger stage the balancer-building properties of *Pleurodeles waltlii*, as well as those of *Triton taeniatus*, are not confined to the spot of balancer origination, but are spread all over the epithelium outside this spot. At the next stage the results of the experiments were different: *T. taeniatus* developed a balancer at the operated side simultaneously with the one on the opposite side. Unlike this, in *Pleurodeles waltlii* the spot of operation remained smooth, the balancer failed to appear, either simultaneously with that on the opposite side, or later. This experiment shows that in the interval between the two stages taken for experiment, the younger and the older; *Pleurodeles waltlii* underwent a differentiation which deprived its epithelium of its balancer-building properties outside the spot of balancer origination. The two experiments made it evident that the process of concentration of the balancer-building properties of the epithelium of a given organism takes place not because these properties are lacking outside the spot of balancer-formation from the beginning of ontogenesis, but because of an early epithelium differentiation, owing to which after a definite stage the capacity of building balancers is left to a very small area of the epithelium only at the spot of balancer-formation. We find here a full analogy with the reduction of the lens-forming capacity of the epithelium. Sheina showed that in organisms which at the stage of normal lens-formation present under experimental conditions great difficulties in obtaining a lens from trunk epithelium; at earlier stages (neurula) the lens is developed from trunk epithelium in almost 100 per cent of cases. Consequently, the focusing of the lens-building properties is brought about in the same way as that of the balancer-building capacities.

My experiments with *Pleurodeles waltlii* have filled the gap between the two stages of the balancer-building epithelium, on the one hand, in *Triton taeniatus*, where these capacities are found to be widespread all over the epithelium; and in the axolotl, on the other hand; in which they have vanished altogether. These

two extreme cases have been found to be connected with the intermediate stage in *Pleurodeles waltlii*, where the capacity of the epithelium to form balancers during ontogenesis disappears very early everywhere, being preserved at the place of balancer-formation.

A similar condition of concentration has earlier been reported for the lens-forming epithelium of many amphibians where it was also preceded by a historical stage of lens-forming properties widely spread all over the epithelium.

When comparing in my previous investigation data available on the states of the lens-forming and balancer-forming properties in various amphibians, it became evident that parallelism is observed only between the stages of wide distribution of the two properties all over the epithelium (if the parallelism between the hypothetical states be put aside). This stage was followed in the series of lens-forming properties by the stage of their concentration, and in that of the balancer-forming, by their total disappearance, at least towards the period of balancer-formation. The parallelism between the two stages is thus disturbed in the two columns. If we were to assume, however, that in the series of balancer-forming properties we still ignore the state of the beginning concentration which exists in some organisms; while in the series of lens-forming properties we are missing the stage of their complete vanishing, then the analogy might prove undisturbed.

It is on this assumption that I have plotted the table on page 12 of my article [1], having kept two blank places for the stages still unknown. The existence of the unknown stages could be presumed only on the ground of a comparison of the two columns (stages of the lens-forming properties and stages of the balancer-forming properties of the epithelium). The comparison gave some ground to suppose that the distribution of these properties varies under the influence of epithelium differentiation setting in at a more and more early date. Being controlled by selection, differentiation leads at first to a concentration of the organ-building properties of the epithelium at the spot of the future organ, in front of the determining source; later on, if the organ ceases to be necessary in the general economy of the organism, this last islet is also found to be removed.

The import of the experiment described consists in that by having confirmed the correctness of the hypothesis as to the existence of the above gaps, it has also confirmed the correctness of our conception of the historical process which had led to the creation of different conditions for the building of the lens and of the balancers. It has also checked the correctness of the method used to trace the future of anlage by studying the stage by which it is preceded, when the material of the anlage is being determined by the material lying outside it.

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